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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 220.
B. T. GALLOWAY, *Chief of Bureau.*

RELATION OF DROUGHT TO WEEVIL RESISTANCE IN COTTON.

BY

O. F. COOK,
Bionomist in Charge of Crop Acclimatization and Adaptation Investigations.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., April 15, 1911.

Sir: I have the honor to transmit herewith a paper entitled "Relation of Drought to Weevil Resistance in Cotton," by Mr. O. F. Cook, of this Bureau, and to recommend its publication as Bulletin No. 220 of the Bureau series.

It has been ascertained that dry weather gives a distinct advantage in the production of cotton in the presence of the boll weevil. This relation is being taken into account in improving varieties and cultural methods in the direction of weevil resistance. The present report shows that several biological factors must be considered in the study of the practical problem of securing a rapid, uninterrupted development of the crop.

Respectfully,

Wm. A. Taylor,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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RELATION OF DROUGHT TO WEEVIL RESISTANCE IN COTTON.

INTRODUCTION.

An important relation between weevil resistance and drought resistance has been recognized for several years past. Special ability to resist drought is to be reckoned as one of the factors of weevil resistance, because more drought-resistant varieties can be grown in the drier regions of the Southwest, where the weevils are often unable to propagate and do relatively little damage. A rapid extension of cotton culture is taking place in this part of the United States.

The farming public in Texas is coming to look upon dry weather in the early part of the season as the most important factor in the production of a good crop of cotton. At first it was supposed that the fate of the weevils during the winter would determine the possibilities of production in the following season. Measures for reducing the number of weevils in the fall and spring received much attention, but it is now understood that dry weather makes it possible to secure a crop, even in a season when the weevils survive the winter in large numbers. In southern and western Texas the reduction of weevil injuries by drought is a very definite factor of weevil resistance, tending to place these regions more nearly on a basis of equality with other parts of the State for purposes of cotton production. In favorable seasons the same factor of dry weather becomes effective over much larger areas, as notably illustrated in the last two years, 1909 and 1910.

In order to take full advantage of other measures for combating the weevils, the relation of drought to the behavior of the growing plants must be considered, no less than the direct effect of the drought upon the weevils. Questions of the value of early and late varieties and of early and late planting require to be reconsidered and given further study now that the effects of dry weather are more fully appreciated. It is only by a careful study and full recognition of all the factors that the true possibilities of cotton culture in the presence of the weevils can be realized.

Without a supply of moisture in the soil the same drought that hinders the reproduction of the weevils will also stop the growth of the plants, thus reducing the advantage that might be gained from the dry weather. But if the land has been well prepared by deep plowing and thorough cultivation so that it absorbs and retains moisture, the plants continue to grow and set their crop through the dry weather. The weevils do not prosper during drought because the young larvæ are killed when the infested buds fall off and lie exposed on the hot, dry ground. The importance of thorough tillage is especially great in the very compact impervious soils of the "black-land prairies" that produce a large part of the Texas cotton crop. Unless such soils are stirred by cultivation very little water penetrates beyond the surface layers, and these are very soon dried out.

Under conditions of humidity other factors determine the success or failure of the crop. Wet and cloudy weather is likely to interfere with the growth of the plants without checking the propagation of the weevils. The more humid the climate the greater the necessity for a rapid, uninterrupted development of the plants if a crop is to be set before the weevils can prevent.

With conditions continuously favorable the weevils can seldom cause any complete loss of the crop, but if a period of unfavorable weather interrupts the growth of the cotton after the first crop of buds has been infested, enough weevils may be bred to infest all the subsequent buds, so that no crop can be set. The luxuriant growth of the plants may continue, each producing hundreds of flower buds, but all pruned off by the weevils. A whole field of the overluxuriant weevil-pruned cotton may not average more than two or three bolls to the plant.

The idea of avoiding weevil injuries by early planting needs to be supplemented by a recognition of the importance of securing an uninterrupted development of the plants. The chief object to be attained is the early setting of the crop in as short a period as possible after the plants have begun to produce flower buds in which the weevils can breed. This object should be taken into account in the breeding and adaptation of varieties and in devising improved methods of culture for weevil-infested regions.

COMPLETE CESSATION OF WEEVIL INJURIES DURING DROUGHT.

The condition of the cotton on the San Antonio Experiment Farm in the middle of July, 1909, afforded an unusually striking illustration of the importance of dry weather as a factor of cotton production in Texas. In spite of the fact that weevils appeared very numerous in the same fields early in the season and infested nearly

all of the first buds, no damage was being done in the middle of July, nor were there evidences of any recent injuries by weevils. A careful search over several different plats of cotton failed to find a single bud, or "square," with a normal weevil puncture. Weevil larvæ could still be found in very small numbers in old squares on the ground under the plants, but almost invariably dead or dying. Not a single adult weevil was found. The only weevils that appeared likely to survive were a few small larvæ in some of the earlier bolls, and these would not do further injury in that season, for the larvæ develop very slowly in the bolls and are not likely to emerge until the bolls open at maturity.

Careful examinations of the same plats had been made by Mr. S. H. Hastings, superintendent of the San Antonio farm, in May and June, when an unusually heavy infestation of weevils was found. Under date of June 14, Mr. Hastings reported that nearly all the buds had been destroyed by the weevils as fast as they were formed and that a total failure of the crop was threatened. Had the weather continued favorable for the weevils there was certainly no prospect that the later buds could have fared any better than their predecessors, but the advent of dry weather completely changed the situation and set a definite limit to the activities of the weevils. Similar cases had been observed in previous years when there seemed to be a lessening of weevil injuries as the season advanced instead of the increase that had been feared, but no such complete interruption of injuries by weevils during the growing season of the cotton had been observed.

The effects of heat and dryness upon the weevil larvæ were doubtless intensified indirectly by the influence of the drought upon the plants. Injured buds are dropped much more promptly in dry weather, and in severe drought even the uninjured buds may fall off, thus lessening still further the weevil's opportunities of propagation. The result of the earlier falling of the infested buds is to expose the larvæ to adverse conditions at earlier stages in their development and for longer periods of time.

The effect of the prolonged drought in completely preventing the continuation of the weevil injuries was not confined in the season of 1909 to the vicinity of San Antonio. The same condition of unusually heavy infestation appeared early in the season in the experiments conducted at Waco, Tex., by Dr. D. A. Saunders, and the same complete cessation of weevil injuries was observed with the advance of drought. Careful examination of several fields of cotton in the vicinity of Waco on August 18 and 19 by Dr. Saunders and the writer showed that no injury was being done by the weevils, though the insects remained active in more luxuriant fields on rich bottom lands of the same district.

Though the conditions of drought that gave the complete protection against the weevils were generally so severe as to interfere seriously with the growth of the plants and would undoubtedly have prevented the development of any considerable crop unless rain had come, the facts are of interest in their practical bearings upon the problem of weevil resistance. The complete cessation of weevil injuries, even after the weevils had survived the winter in unusual numbers and had begun to feed and breed in the buds of the young plants, makes it evident that the highest importance must be placed on the dry weather. The values of special weevil-resisting varieties and of special methods of culture must also be considered as means of gaining greater advantages from dry weather.

EARLY PLANTING IN DRY REGIONS.

The object that has been sought by early planting and by the use of early varieties is to give the cotton an opportunity to set as many bolls as possible early in the season, before the weevils have become numerous enough to infest all the buds and bolls and thus set a limit to the crop. A farmer who plants too late may have his cotton stocked with weevils from fields planted earlier by his neighbors and may suffer more seriously than they.

The best plan would be for a community to plant all of its cotton as nearly as possible at the same date. The date should be selected with a view to securing the most rapid development of the crop, and for this it is necessary that the plants make prompt and continuous growth. The amount of weevil injury is determined by the relation between the development of the cotton and the reproduction of the weevils. Any loss of time on the part of the cotton by delay or interruption of growth can only increase the relative proportion of weevil injury and diminish the crop. Anything that gives the cotton an advantage over the weevils should be taken into account in the problem of weevil resistance, whether the advantage is gained by methods of culture or by specialized characters of the plants themselves. The largest results are to be obtained by combining the cultural and the biological factors.

If each farmer attempts to plant earlier than his neighbors, the product of the community is likely to be reduced, for two reasons: Cotton that is planted too early may be injured so that maturity is retarded instead of being hastened and the weevils bred in early cotton may inflict increased injuries upon the later fields. Cotton that has been severely checked by cold or by extremes of wet or dry weather in the early stages of growth often suffers a permanent injury, either by being stunted in growth or by becoming abnormal in other respects. A smaller crop is obtained and that of inferior

quality. And even if no other change of characters takes place, experiments at San Antonio, Tex., in 1906 showed that the checking of the growth of an early planting may render it actually later in the development of its crop than a later planting of the same variety in the same place. Later planting not only secured more cotton, but a larger part of the crop was ripened before a given date, in spite of the fact that the plantings were made side by side, so that the later rows were readily accessible to the boll weevils bred in the early rows.[1]

That the same result would be obtained in all cases is not to be expected, for these experiments were made under dry-weather conditions. But in the season of 1906 the summer drought was not severe enough to stop the reproduction of the weevils, all the plantings being quite seriously infested. The later plantings might have shown still greater superiority if they had been isolated from the early plantings, but in that case there could have been no assurance that other conditions of soil and moisture were the same.

If very early planting could insure a correspondingly early harvest, it might be argued that cotton should always be planted at the earliest possible date, without reference to scarcity or abundance of weevils. But in view of the experiments mentioned above, showing that later plantings may overtake very early plantings and ripen an earlier crop, it is plain that early planting, like any other cultural expedient, must be used with discretion and not carried to an unpractical extreme.

Of course, it is only in regions subject to drought that the weevils can be expected to become less destructive as the season advances, but in the dry regions of southern and western Texas this consideration seems to be of practical importance. Fields planted in May sometimes mature a full crop before being invaded at all by the weevils, even in localities where fields planted in March have suffered quite severely. Though such complete immunity of late plantings from weevil injuries may be of rare occurrence, the fact that good crops are sometimes secured in this way often leads the farmer to take the chance of a late sowing of cotton after a winter crop has been harvested or after some other spring crop has failed. The possibilities of late planting are obviously of much more importance in regions where winter crops can be grown than in more northern localities where the growing season is only long enough for the cotton and winter crops are not used, at least on land that is to be planted to cotton.

A heavy infestation of boll weevils in the early part of the season interferes with the growth of the plants long before the fruiting

[1] See "Local Adjustment of Cotton Varieties," Bulletin 159, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 49.

stage is reached. The weevils begin by gnawing the terminal vegetative buds in the spring, before there are any flower buds to feed upon. This hinders growth of the young plants and forces the growth of vegetative branches at the base of the plants instead of allowing fruiting branches to be produced early in the season. Weevil-infested fields of cotton can often be recognized, even at a distance, by changes in habits of growth, before the differences in yield become apparent. Such expedients as the picking of the adult weevils by hand and the poisoning of the leaf buds of the young plants are much more advantageous early in the season, not only in reducing the number of weevils, but in allowing the cotton to make more rapid and normal growth. Yet it is very difficult to determine how much advantage is secured from such efforts, owing to the great variation in seasons and in the abundance of weevils in different fields, or even in parts of the same field.

Drought is more effective in holding weevils in check if the dry weather begins before the cotton plants are large enough to provide the necessary food and shelter for the weevils. If the plants continue to make good growth during weather that is too dry for the weevils to propagate, the crop can be set and brought to maturity without serious damage, even in localities where earlier plantings have suffered severely from the weevils. This explains the very great advantage that is generally to be gained in dry regions by plowing the land in the fall and maintaining the tilth through the winter as a preparation for the planting of cotton, in order to have as much moisture as possible available in the soil and thus enable a more continuous growth to be made during any periods of dry weather that may occur in the early part of the growing season.

With proper attention to the preparation of the land, cotton can be grown even without irrigation in many districts of the Southwest that have been looked upon hitherto as hopeless deserts. The drought-resistant qualities of the cotton plant are only beginning to be appreciated, perhaps because the chief centers of production have been located in humid regions. In localities where small supplies of irrigation water can be developed they can probably be used to much better advantage with cotton than with any other crop. The general danger in irrigated regions is the excessive use of water. The chief obstacle to the extension of cotton culture in the Southwestern States is the scarcity and high cost of labor, but the progress that is being made in the invention of cotton-picking machinery indicates that this limitation may be removed in the near future.

IMPROVEMENT OF QUALITY BY CULTURAL METHODS.

Cultural methods that allow a continuous development of the plants may also help to counteract weevil injuries. Interruptions of growth not only invite greater damage from weevils but injure the quality of the fiber. If the presence of the boll weevil can induce the farmer to adopt better methods of culture, better staples can be produced, so that a lessening of the crop may be compensated by an increase in value. To improve the fiber so as to be able to sell small crops for as much or more than the former large crops would be a very practical method of reducing the losses inflicted by the weevils. Reduced production of long-staple Upland cotton in Louisiana and Mississippi is increasing the demand for superior varieties of intermediate lengths, from an inch to an inch and a quarter. These can be grown in many parts of the cotton belt where only short and inferior varieties are now planted.

With the boll weevil as a further obstacle the tendency is for the careless farmer to give up the culture of cotton, but farmers who adopt the other precautions to make cotton profitable under weevil conditions are likely to take the additional step of adopting better varieties and maintaining the uniformity of their stocks by the necessary selection.

Longer and stronger staples could be produced over a large part of Texas if better varieties were grown and better methods of culture were applied, so that the fiber could be properly ripened instead of growth being suddenly checked by drought and the bolls opened prematurely. Even under conditions of extreme drought it is possible to produce fiber of good quality if the plants are not checked. Though plants that develop under dry conditions may remain very small for lack of moisture, they may still produce excellent lint. This was well shown in experiments at San Antonio, Tex., in 1910. A season of continuous drought produced better fiber than the previous year when the drought was interrupted by a rain at the middle of July. The rain allowed a larger growth of the plants, with larger demands for moisture, but no other rains came to maintain the supply. Though the rain undoubtedly increased the crop, much of the fiber suffered in quality because the plants were checked during the fruiting period and the bolls opened prematurely.

In localities where irrigation facilities exist, even a very limited supply of water could be utilized to great advantage in bringing the cotton crop through to maturity. Where water is to be had in the winter, but without facilities for summer storage, winter irrigation may be practiced as a preparation for the cotton crop, the water being retained in the soil by the same methods of tillage as in dry farming. There is an unfortunate tendency in irrigated districts to apply

water to the growing plants too early in the season. The result is to stimulate an undesirable vegetative growth and make the crop late, thus increasing the danger of weevil injuries.

In the drier districts of southern and western Texas the farmer depends more upon the moisture already stored in the soil than upon rain that falls during the growing season. To raise a crop of cotton without any rain on the plants would seem an impossibility in many humid regions, but this can often be done in dry regions if the previous rainfall has been conserved in the soil by proper tillage. Indeed, it is possible to have too much water stored in the soil and thus make the plants too luxuriant, just as it is possible to have too much rain.

Under such conditions there is the less reason to urge the importance of very early planting. In experiments with successive plantings of Triumph cotton at San Antonio, Tex., in 1906, the April and May plantings grew quite as large as the March plantings, showing a practical equality of the available supply of soil moisture, which was the limiting factor in this experiment. The surface of the soil becomes drier as the season advances, so that recourse to previous wetting of the seed or to somewhat deeper planting may become necessary to secure a good stand, but the easier cultivation and greater freedom from weeds in dry weather more than compensate for extra precautions in sowing.

LATER PLANTING IN BLOWING SOILS.

In addition to the loss of moisture and the checking of the plants by weather too cold for growth to be made, early planting increases the danger of the "blowing out" of the seedlings in some of the sandy districts of southern Texas that are otherwise well adapted for cotton. The surface soil may be drifted away and the plants broken down by the wind or the young stems may be actually cut away by the blowing sand. The winds are said to be much more severe as a rule in March than in April, and in districts where this is true it might be better if all plantings could be deferred till the later month. Even though the winds were as severe in April as in March the crop is less likely to be injured if the period of exposure is shortened. It is also easier to keep the soil from blowing before the cotton is planted, by throwing the surface of the field into ridges.

In addition to the possibility of avoiding injury from the wind, the April plantings are likely to have the advantage of more continuous growth. This not only favors an earlier and larger crop, as already explained, but tends at the same time to increase the length and the uniformity of the lint. The proportion of aberrant plants that are likely to appear in a variety of cotton depends to a

considerable extent upon whether the plants are severely checked in the early stages of development or make uninterrupted growth.

LIMITATIONS OF LATE PLANTING.

If whole communities could be organized so that all the cotton could be planted at the same time and all the plants destroyed in the fall, so that none would survive the winter, later planting would become more feasible than at present; but other interests of the crop forbid very late planting.

In the northern districts of the cotton belt it is not safe to shorten the season by deferred planting, and even in places where the season is long enough the habits of the cotton plant set limits to late planting. If the weather is too hot during the early stages, the fertility of the plants suffers through a change in the habits of growth. Fruiting branches are not produced so near the ground as in earlier plantings, but are replaced by more numerous upright vegetative branches. With plenty of moisture such plants become large and bushy and produce a late crop, at the mercy of the weevils. Or if dry weather cuts off the supply of moisture the growth of the late plants is checked before the fruiting stage is reached, so that little or no crop can be set.

Under conditions of drought, the tendency to excessive vegetative growth of the young plants may be restricted by lack of water in the surface soil. This is another reason why late plantings are more likely to be successful in seasons when the drought is severe enough to check the multiplication of weevils. Thus at Palestine, Tex., in the season of 1909, some fields of cotton planted in June, after the harvesting of a crop of potatoes, developed normally and gave larger yields than neighboring fields planted much earlier, in April or May. In a wet season such late plantings might be a complete failure. The fruiting stage would probably not be reached until the weevils had time to multiply and destroy the whole crop.

Varieties differ in the readiness with which their characters are changed in response to differences of cultural conditions, some being more suitable for late planting than others. The tendency to deferred fruiting and to the production of excessive numbers of vegetative branches is still stronger in the Egyptian cotton than in the Upland series of varieties. Early planting of Egyptian cotton has been found necessary in Arizona as a means of controlling the growth of the plants, though no weevils exist.

Planting too late also interferes with the early destruction of the stalks, a most desirable measure for reducing the number of weevils that survive the winter. The earlier this work can be done the more successful it is likely to be, for the principal object is to deprive the

weevils as early as possible of food and of facilities for breeding. If this work is postponed until the plants are killed by frost, much of the advantage of removing the stalks is lost, though it may still be very important to destroy the unripe bolls, which sometimes carry many weevil larvæ through the winter. In some districts the pasturing of the cotton fields in the fall is very useful, for the cattle eat the buds and green bolls with the weevils and larvæ that might otherwise be left in the fields.

Another factor that tends to limit late planting in Texas is the prevalence of root-rot. As the attacks of this disease are often deferred till the latter part of the season, the plants that are killed may not represent a total loss. Some of their bolls may be ripe before the plants are killed, and the remainder are opened prematurely by drying, so that the lint, though often weak and worthless, can be picked and sold with the rest of the crop. In some parts of Texas fields are often seen with half the plants dead from root-rot before the middle of September, though half or three-quarters of the crop may be already mature. If the crop were to be deferred by late planting, root-rot injuries might involve a total loss. In such cases the root-rot, rather than the boll weevil, may be said to determine the necessity for early planting.

RELATION OF DROUGHT TO WEEVIL-RESISTANT HABITS OF GROWTH.

Recognition of the importance of dry weather brings a new factor into the question of weevil-resistant habits of growth. If it be considered a matter of first importance to lessen the number of weevils that go into hibernation in the autumn, it appears to be essential to use the earliest and most determined varieties, so that the crop can be completed at the earliest possible date, and thus leave the weevils without opportunity to breed for as long a period as possible before winter. It happens, however, that some of the best of the early varieties, such as the Triumph cotton of Texas and the Kekchi cotton of Guatemala, have low, compact habits of growth that undoubtedly tend to interfere with the beneficial effects of dry weather in killing the weevil larvæ. Fallen squares are much more effectively shaded by a low, compact plant than by one that bears its foliage farther up so that all of the ground under the plant is exposed directly to the sun during at least a part of the day. Plants that stand well up from the ground and allow the sun to reach and dry out the fallen squares and kill the weevil larvæ are able to secure in this way a distinct advantage over the low, compact plants that shade the fallen squares and protect them from the dry winds.

Many of the experimental plats at San Antonio in 1909 consisted of Triumph cotton. The low, compact form of the plants was well

calculated to shade fallen buds lying under them, though even in such buds the weevils did not appear to prosper under conditions of very extreme drought. But an adjacent planting of a newly acclimatized Mexican type of Upland cotton gave much less shelter for the weevils. No leafy branches were developed at the base of these plants until after fruiting had begun, so that the early foliage was borne well up from the ground.

This Mexican variety had not been supposed to have any specialized weevil-resisting characters, although it had given very favorable results under weevil conditions. The contrast in behavior between this variety and the Triumph was very striking, the Mexican cotton having much less tendency to put out branches from the lower joints of the stem.

Partly as a result of later planting and partly because of its different habits of growth, this cotton continued to develop slowly during the dry weather of May and June and was ready when rain finally came in July to put on very quickly a good crop of bolls. The tendency to ripen all of the bolls at one time has been shown in several other experiments and is to be reckoned as a very desirable characteristic of this type of cotton. It lessens the labor of picking and allows the fields to be cleaned of the old stalks early in the fall.

The behavior of this Mexican type of cotton may be contrasted in many ways with that of the Kekchi cotton from Guatemala. The Kekchi cotton has several definite weevil-resisting adaptations not possessed by the Mexican cotton, such as hairy stems and leaves that restrict the movements of the weevils, large, hairy, well-closed bracts that impede the access of the weevils to the young buds, and long pendent or creeping basal branches, the buds and bolls of which are seldom attacked because of the strong instinct of the weevils to climb up the plants instead of remaining on the lower branches or crawling downward. But in southern Texas, where most of the experiments with cotton have been made, some of the weevil-resisting characters have cultural disadvantages. Although the lower branches often continue to produce buds and bolls long after the weevils have halted all the other types of cotton, the additional bolls are borne so near the ground that they are often soiled by blowing sand or muddied and rotted by rain. Bolls produced underneath the plant often rest on the ground and are also subject to mildew and other diseases. An attempt is being made to avoid these disadvantages by selecting more erect forms of the Kekchi cotton that carry their bolls clear from the ground and thus enable the several desirable features of this type of cotton to be utilized. In addition to the weevil-resisting characters, some of the acclimatized strains of the Kekchi cotton have shown themselves very early and productive, and with lint of good Upland quality.

It is easy to understand that a variety with a rapid-fruiting habit like the Mexican cotton would be even more likely to have definitely determinate growth than an early-flowering variety like the Kekchi. The small size of the plants of early varieties may be ascribed to the fact that vegetative growth is less rapid after fruiting commences and if dry weather ensues an extra early variety may mature and cease to grow even under the same conditions that permit another variety with later fruiting habits to continue its development. Determinate habits of growth, like other desirable things, may be carried to excess. If selection for earliness be directed solely to the question of early flowering or early opening of bolls the effect on yield may be adverse. Very early flowering or very early opening of some of the bolls is not in itself a guarantee of the practical weevil-resisting value of a variety. Varieties that flower very early may develop more slowly or attain a precocious maturity if exposed to dry weather or to other unfavorable conditions that interrupt the growth of the plants.

IMPORTANCE OF DRY WEATHER IN HUMID REGIONS.

In cooler and more humid regions the importance of the drought factor must of necessity decline. Unless the weather is hot and dry enough to interfere with the propagation of the weevil larvæ, the direct advantage secured from drought in a dry climate is not obtained. A humid climate with heavy dews may allow unimpeded development of weevils, even in the absence of rain. Yet there is a very important indirect advantage in a period of dry weather, even though the conditions are not severe enough to destroy the weevils. Too much moisture interferes with the development of the cotton plant, either by stunting its growth or by causing the shedding of buds and young bolls. In a district where there are no weevils such a shedding may do little damage, for the plants continue to produce buds and can soon replace the loss, but with the weevils present the loss of the early crop by shedding becomes a much more serious matter.

In a continuously humid climate the early buds must be expected to furnish the crop, for all the later buds are likely to be destroyed by the weevils. There must be no delay in the development of the cotton if a crop is to be set before the insects become destructively numerous. The closer the race becomes between the cotton and the weevils, the more important it is that the plants lose no time in development and that the crop receive no setback by the shedding of buds or bolls. Every precaution that favors the quickest possible development becomes worthy of careful consideration, such as the planting of the cotton in dry, well-drained soil, thorough preparation and cultivation, and the application of fertilizers.

One limitation must be recognized in all such efforts. It is possible in some regions to stimulate the cotton into an excessive vegetative growth, and thus defeat the object of securing an early crop. If the plants make too rank a growth at first, fruiting is likely to be deferred, the lower fruiting branches being replaced by vegetative limbs.[1]

DIFFERENT TYPES OF EARLINESS IN RELATION TO WEEVIL RESISTANCE.

The ideal form of earliness for varieties that are to be grown in humid regions is not extreme precocity in showing the first flowers or the first ripe bolls, but the production of the crop as rapidly as possible after fruiting begins. Even the early varieties are not so early in humid regions as in dry, for abundance of moisture conduces to more vigorous vegetative growth and to the production of vegetative limbs near the base of the plant instead of fruiting branches. In a continuously humid region an early-fruiting variety would have no advantage over one that began to fruit a little later unless the later variety were attacked by weevils bred on the early variety, in case both were planted in the same locality.

If all the cotton in a humid district began to bud and blossom somewhat later but had the rapid-fruiting habit, it would have two advantages over an early-fruiting variety in relation to the weevils. A smaller number of weevils would survive until the late variety began to fruit and the late variety would be able to set the same amount of crop in a shorter period, after it had once begun to fruit. Late varieties that differ from early varieties in completing a larger amount of vegetative growth before they begin to fruit should be able to produce fruit more rapidly after fruiting has once begun.

Rapid fruiting, rather than early flowering or early opening of bolls, represents the most effective form of weevil resistance under conditions of continuous humidity. Other things being equal, there is more reason to expect fruiting to go on rapidly in varieties that begin to bud and flower rather late than in those that flower very early. A variety that begins to flower very early is likely to require more time to produce the same number of bolls than a later flowering variety. The relatively small size of the plants of all the early-flowering types may be taken as evidence that the very early production of fruit tends to check vegetative growth. In other words, earlier flowering may lead to slower fruiting, if account be taken of the total number of bolls or the quantity of cotton ripened within a given period.

[1] See "Dimorphic Branches in Tropical Crop Plants," Bulletin 198, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1911.

A later date in flowering is not to be reckoned as a lessening of weevil resistance if a variety sets its fruits with sufficient rapidity after flowering has begun. Until the flower buds are about half grown the weevils can not begin to reproduce. The rapidity with which bolls are developed within a specified time after the buds are large enough to allow the weevils to begin to breed would serve as a measure of weevil resistance in experiments with varieties in humid regions. It is important to establish such standards and to apply them to all varieties that are to be grown under weevil conditions, whether the weevils are already present or not.

In attempting to determine the rate of setting of the crop in different varieties, special precautions must be used. It is not sufficient to compare the yield in early pickings, for this will give an undue advantage to the factor of early opening in small-bolled varieties. Neither is it sufficient to determine the tendency to fruit production by the daily counting of flowers on experimental rows or plats representing the different varieties. Allowance must be made for the fact that a big-boll variety does not need to produce as many flowers in order to set the same amount of crop in the same number of days as a small-boll variety. Daily countings of the numbers of flowers on adjacent rows of different varieties may also be rendered unreliable by differences in shedding, some varieties dropping their buds and young bolls much more readily than others.

The counting of the full-grown bolls at different dates would give an indication of the crop-setting habits if there were any ready means of determining when the bolls have reached full size. For the most accurate determination it would be desirable to make counts of the bolls as fast as they became large enough to escape weevil injury, though it would still be necessary to take into account the differing amounts of cotton represented by the same numbers of bolls of different varieties.

It may be that the rapidity with which the bolls are opened corresponds to that with which they are set, but there is no definite information on this point. It has been noticed in some plantings of Mexican cotton that the bolls seemed to open more nearly together than those of the Triumph cotton and other United States Upland varieties grown in the same places. The rate of opening of the bolls depends very largely on the weather at the time when the bolls reach maturity, but these experiments were made under dry conditions, with equal opportunities for opening.

It was generally assumed at first that small-boll varieties must have a distinct advantage in weevil resistance because of earlier flowering and earlier opening of the bolls. Large importations of seed of the King and other small-boll varieties from the Carolinas were brought in to replace the Texas big-boll sorts in weevil-infested

districts. Nevertheless, the small-boll cottons have not gained any general popularity in Texas, most farmers having returned to the native big-boll varieties. Additional familiarity with the factors that determine production under weevil conditions makes it possible to understand why the big-boll varieties do not show any such serious disadvantage in weevil resistance as at first expected.

The larger bolls require longer periods for full development, but during most of the time they are beyond the danger of weevil injury. The growth of the bolls continues longer after the crucial stage of weevil infestation has been reached. A big-boll variety that could produce as many flowers and set as many bolls in the same number of days as a small-boll variety could yield a larger crop in proportion to the increased size of the bolls, or larger bolls may make up for a deficiency in the number of flowers. The few observations that have been made do not indicate that big-boll varieties fall very seriously below the small-boll sorts in their rates of flowering and boll setting. The production of flowers and young bolls may not make larger demands on a big-boll variety than on a small-boll type. If the weevils are to prevent any further boll setting after a certain date, a big-boll variety has the advantage of being able to produce more cotton in each of the bolls that reaches maturity.

In districts where the season of growth is very short, early opening of the bolls may be necessary to avoid the danger of frost, but in a large part of the cotton belt the lapse of a few more days before the bolls begin to open is not to be considered as a serious disadvantage and is not likely to outweigh the stormproof qualities, easier picking, and other desirable features of the big-boll varieties. It is quite possible that the Texas big-boll type of cotton may be found less satisfactory in humid regions and that special selection may be necessary under the new conditions to establish local strains with uniform expression of earliness and other desirable characters. In the drier regions of central and southern Texas, where the growth of the plants is usually limited by drought, the same general tendency to early fruiting appears in the big-boll and small-boll types, but greater differences may be shown where more abundant moisture provides for more luxuriant growth.

IMPORTANCE OF RECOGNIZING FACTORS OF WEEVIL RESISTANCE.

Too much stress can be laid upon early varieties as well as upon early planting, because both these factors lose in effectiveness if pushed to extremes. Cotton planted too early may develop more slowly than cotton planted later, and varieties that begin fruiting too soon may take longer to develop a full crop. These considerations are well-nigh self-evident when once pointed out, especially when viewed in relation to the dry-weather factor. If the benefits

exerted by dry weather are ascribed to early planting alone there is danger that the farmer may rely too much upon the date of planting and fail to appreciate the still greater importance of tillage and other means for securing an uninterrupted development of the crop.

That the production of cotton has been maintained in Texas has been taken generally to mean that the weevil menace was exaggerated. This may be true to the extent that the susceptibility of the insect to dry weather was not at first appreciated. In some localities the first seasons of weevil infestation were unusually wet. The destruction wrought by the weevils in the wet seasons was expected to continue every year, and the very existence of the cotton industry seemed to be threatened. At present the tendency is rather to the other extreme of optimism, on the assumption that the same results are to be expected over the whole cotton belt as in Texas. Such reasoning may prove erroneous, especially in regions that are subject to continued rain or damp weather in the early part of the growing season. Continued wet weather is always unfavorable to the cotton crop, no matter how satisfactory the other conditions may be. The losses occasioned by wet weather become the more serious if weevils are present to prevent the setting of any later crop of bolls.

In many cotton-growing districts the soils are so heavy and adhesive that the fields can hardly be entered for two or three days after each rain. In localities where the soils are varied much can be gained by choosing the driest and best drained land for cotton, but rain may still interfere with the cultivation of the fields and prevent the gathering of the weevil-infested squares.

Even in places where good yields can be obtained in favorable seasons the growing of cotton may become unpopular if the crop becomes too precarious. In the more humid sections of the coast belt of Texas, for example, some of the most progressive farmers consider the future of cotton culture as doubtful. Those who have been careful to clear their fields and destroy their stalks early in the fall and give their land good preparation and tillage have found it possible to raise good crops of cotton in spite of the weevils. In other seasons, when too much rain interfered with cultivation and the plants grew too large and shaded the ground before the bolls were set, the crop was seriously reduced or became a total loss. Nevertheless, the prevailing high prices have encouraged the taking of larger chances on the cotton crop, even by farmers who previously declared their intention of abandoning cotton altogether.

EARLIER LONG-STAPLE VARIETIES.

The practical questions of weevil resistance vary in different regions, like other cultural problems. In the Texas short-staple districts an immediate advantage was obtained by the use of earlier

short-staple varieties. In long-staple districts the need of earlier varieties is still more acute. The introduction of the early short-staple varieties into the long-staple districts is not calculated to preserve the long-staple industry. There can be little doubt that the difficulty of producing the long staples is increased by the growing of the short-staple varieties in the same neighborhood. More weevils are bred early in the season in the short-staple fields. There is also more danger of admixture of the long-staple with the short-staple varieties, either by cross-fertilization in the fields or by the mixing of seed at the public gins.

Even before the weevils came, the manufacturers complained that the long-staple varieties were deteriorating, because the fiber was becoming less uniform. This has been ascribed to the fact that more and more of the ginning has been done in recent years at large public gins where the seed of the whole community becomes mixed, instead of at the smaller private plantation gins which gave much less opportunity for such admixture. If the long-staple varieties continue to decline in uniformity at the same time that the yield is being cut down by the presence of the weevils, there is less prospect of an ultimate survival of the long-staple industry.

The need of quick-fruiting long-staple varieties has been recognized in advance in the cotton-breeding work of the Department of Agriculture. Two such varieties have been developed and distributed, the Columbia cotton, originated by Dr. H. J. Webber, in South Carolina, and the Foster cotton, bred by Dr. D. A. Saunders for the Red River Valley of Louisiana and northeastern Texas. These varieties are not only distinctly earlier, but are also more productive than the older long-staple sorts. In their habits of growth they are much more similar to short-staple Upland varieties and they seem to yield at least equally well. Some of the Columbia cotton raised in the season of 1910 has been reported as selling as high as 24 cents a pound. While this price may be considered exceptional, there can be no doubt that a very general increase in the value of the cotton crop could be secured by replacing the present short and variable stocks with such varieties as the Columbia and the Foster.

The early-maturing characteristics of these varieties give them almost the same advantages of weevil resistance as the early short-staple varieties that are now being grown in former long-staple districts. The chief difference is that prolonged drought is a greater danger to the long-staple crop than to short staples. The difference is not so much in the ability of the plants to withstand dry weather as in the requirement of continuous growth, if uniform length and strength of fiber are to be secured. If the growth of the plants be checked during the fruiting season, shorter and weaker fiber is the result and the whole crop is injured by the lack of uniformity. The

higher requirement of uniformity limits the production of long-staple cotton to districts where the soil moisture is adequate or is supplemented by irrigation. The irrigation facilities being developed in many localities in southern Texas may make it possible to extend the cultivation of long-staple varieties to a new region.

It remains to be seen whether cotton-growing communities can be organized to take full advantage of early long-staple varieties that have been developed. The size of the crop and the uniformity of the product may both be increased if whole communities, instead of scattered individual planters, can devote their time to the production of long-staple varieties. The preservation of the necessary uniformity of the long-staple varieties will become much easier if no short-staple types of cotton are grown in long-staple communities. The deterioration of varieties through cross-fertilization in the field and by the mixing of seed at gins can both be avoided in well-organized communities that limit themselves to one superior variety of cotton.

DIFFICULTY OF DIRECT TESTS OF WEEVIL RESISTANCE.

One of the chief obstacles in the study and general application of the factors of weevil resistance lies in the great difficulty of making any comparative tests that will definitely determine the actual values even of factors that have obvious practical importance. It is not reasonable to disregard these factors because of the difficulties of testing them. Fortunately there is no possible conflict between the cultural methods that are advised for purposes of weevil resistance and those that are calculated to secure maximum production, even without weevils.

In the case of early and late varieties the planting of the two side by side is likely to give an exaggerated idea of the benefits of earliness. It is certainly to be expected that a row of late cotton will suffer much more by being planted next to an early row infested with weevils than if there were no early cotton in the neighborhood. But if the plantings are made in separate fields to avoid the danger of weevils from adjacent rows, the equality of other experimental conditions can not be assured. Differences of yields at the end of the season can not be ascribed with any confidence to weevil differences alone. The soil may differ in fertility or in the content of moisture and cause wide fluctuations of the crop, even in regions that have no weevils. All other considerations are likely to be overshadowed and forgotton when the weevils are at hand. Nor does the use of isolated fields give any assurance of equality in the numbers of weevils. Even in parts of the same field the extent of damage from weevils usually shows wide variations, often 50 per cent and upward, especially in

the early parts of the season before the period of total infestation is reached.

The planting of the two kinds of cotton side by side insures unfair conditions for the late cotton by breeding an extra supply of weevils close at hand. But if the experiment is made in isolated fields the usual inequalities of infestation may give an unfair advantage to either planting.

A field of late cotton planted by itself might appear at no such disadvantage in relation to weevil injury as would be expected from experiments with early and late rows planted close together. As a matter of fact, it often happens that a late-planted field suffers less from the weevils than fields a mile or two away that were planted a month or six weeks earlier.

But as soon as we begin to compare the different fields more in detail it becomes apparent that many other elements may modify our conclusions. More fertile soil or more favorable temperatures that enable the plants to make more rapid and uninterrupted growth may be the cause of a larger yield, instead of any particular factor of weevil resistance that might have been under investigation and that might have very definite importance in another case. In short, the problem of weevil resistance is not to be separated from other complex cultural problems. The factors of weevil resistance have to be studied and applied from the standpoint of the local conditions that determine the choice of varieties and methods of cultivation.

CONCLUSIONS.

The presence of the boll weevil introduces another factor of uncertainty into problems of cotton production in addition to the usual differences of soils and seasons. The effects of special methods of culture and the special characteristics of varieties should be taken into account in attempting to grow cotton in weevil-infested regions.

Weevil-resisting characters and methods of cultivation are more useful in dry regions or in dry seasons, because the propagation of the weevils is less rapid and the weevil-resisting factors are effective for longer periods. In dry regions the same factor that restricts the growth of the plants also tends to prevent the propagation of the weevils. In humid regions, on the other hand, the growth of the plants may be impeded by wet or cloudy weather that does not restrict the propagation of the weevils.

Wet weather not only favors the rapid multiplication of the weevils, but also interferes with the application of cultural expedients for avoiding weevil injury. Even the weevil-resistant characters of earliness, quick fruiting, and determinate habits of growth are likely to

diminish or to disappear when the plants are grown under extreme conditions of heat and humidity.

Smaller injuries from weevils lend a relative advantage in dry regions and in dry seasons. It is not safe to assume that improved cultural methods, earliness of varieties, or special weevil-resisting characters will have the same value in humid regions that they may have shown in dry seasons in Texas. In the absence of the limiting factor of drought, it is not safe to apply the analogies drawn from Texas to the more eastern States.

The problem of weevil resistance is especially acute in the humid bottom lands of Louisiana and Mississippi, the chief centers of production of the long-staple Upland varieties. Every possibility of weevil resistance in the long-staple district is worthy of careful investigation, because special conditions of soil and climate make it possible to produce superior grades not generally obtainable in other parts of the cotton belt.

Earlier maturing long-staple varieties that have been bred in the United States or acclimatized from abroad may replace the present long-staple varieties whose late-maturing habits render them more susceptible to injury by the boll weevil, especially when grown in the same localities with early short-staple varieties.

Two additional measures of weevil resistance are also worthy of careful consideration in humid regions, the development of quick-fruiting long-staple varieties and the better organization of cotton-growing communities so that only one type of cotton shall be grown in the same locality.

While the use of early-fruiting varieties and the early planting of the crop are important in avoiding weevil injuries, both of these policies have distinct limitations. Very early varieties may be relatively unproductive, and too early planting may check the growth of the seedlings, delay their development, and postpone the fruiting period. The chief object is to secure the most rapid setting of a good crop rather than the earliest opening of flowers or bolls.

The early production of flowers or of ripe bolls does not prove that a variety has the most effective form of earliness for purposes of weevil resistance, especially if this precocious fruiting tends to restrict the growth of the plant. Rapidity of fruiting after fruiting has once commenced is more important than absolute earliness, as shown by the dates of the first flowers or the first open bolls. The setting of a crop of bolls in the shortest time after the flower buds begin to appear is the ideal form of earliness from the standpoint of weevil resistance. This requirement of rapid fruiting should be taken into account in the breeding of weevil-resistant varieties, as well as in devising improved methods of culture for weevil-infested regions.

As the weevils are restricted for food to the pollen of the cotton plant and are unable to begin to breed until the production of flower buds has begun, breeders of new varieties for weevil conditions should consider that plants may gain rather than lose if the formation of fruit buds can be deferred till the roots and other vegetative parts have made considerable progress, especially if this preliminary growth allows the more rapid formation of fruit buds when fruiting has once commenced.

Though later flowering varieties might appear to suffer more from the weevils than the early-flowering varieties if the two were planted side by side, the true agricultural value of a late-flowering variety would not be settled by such an experiment. It is obvious that somewhat later flowering would not be a disadvantage if it shortened the period of setting the crop. Nor would a somewhat later opening of the first bolls be undesirable, especially if there were a tendency for the whole crop to open more nearly together.

The practical value of rapid-fruiting long-staple varieties would also be increased if they were planted by whole communities. The exclusion of earlier short-staple varieties might be expected to give the long-staple varieties less exposure to weevil injuries, and at the same time it would help to maintain the uniformity of the crop by avoiding cross-pollination by bees and admixture of seed in public gins.

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